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Surface Properties of Magnetite in High Temperature Aqueous Electrolyte Solutions: A review

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Abstract

Deposits and scales formed on heat transfer surfaces in power plant water steam circuits, have substantially negative impact on plant reliability, availability and performance causing tremendous economic consequences and subsequent rise in electricity cost. Consequently, the improvement of the understanding of deposition mechanisms on power generating surfaces is defined as a high priority in power industry. The deposits consist principally of iron oxides which are steel corrosion products and usually present in colloidal form. Magnetite (Fe_3O_4) is the predominant and most abundant deposit compound found in water/steam cycle of all types of power plants. The crucial factor that governs the deposition process and influences the deposition rate of magnetite is the electrostatic interaction between the metal wall surfaces and the suspended colloidal particles. However, there is scarcity of data on magnetite surface properties at elevated temperatures due to difficulties in their experimental measurements. In this paper a generalized overview of existing experimental data on surface characteristics of magnetite at high temperatures is presented with particular emphasis on possible application in power industry. A thorough analysis of used techniques, mathematical models and obtained results has been performed and directions for future investigations have been considered. The state-of-the-art assessment showed that for the characterization of magnetite/aqueous electrolyte solution interface at high temperatures acid-base potentiometric titrations and electrophoresis were the most beneficial and dependable techniques which yielded results up to 290 and 200°C, respectively. Mass titrations provided data on magnetite surface charge up to 320°C, however, this technique is highly sensitive to the minor concentrations of impurities present on the surface of particle. Generally, fairly good correlation between the isoelectric point (pH_{iep}) and point of zero charge (pH_{pzc}) values has been obtained. All obtained results showed that the surface of magnetite particles is negatively charged in typical high temperature thermal power plant water, which indicates the low probability of aggregation and deposition on plant metal surfaces. The results also gave strong evidence on decline of pH_{iep} and pH_{pzc} with temperature in the same manner as neutral pH of water. The thermodynamic parameters of magnetite surface protonation reactions were in good agreement with each other and obtained using one site/two pK and mainly one site/one pK model. All collected data provided evidences for interaction between particles, probability of deposition and eventual attachment to the steel surface at various pH and temperatures and can serve as a foundation for future surface studies aimed at optimizing plant performances and reducing of magnetite deposition. In future works it would be indispensable to provide the surface experimental data for extended temperature ranges, typical solution chemistries and metal surfaces of power plant structural components and thus obtain entire set of results useful in modeling the surface behavior and control of deposition process in power reactors and thermal plant circuits. Moreover, the acquired results will be applicable and greatly

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